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RESEARCH MEMORANDUM

INFLUENCE OF END PLATES ON LIFT AND FLOW FIELD OF A CANARD-TYPE CONTROL SURFACE AT A MACH NUMBER OF 2.00

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

RESEARCH MEMORANDUM

INFLUENCE OF END PLATES ON LIFT AND FLOW FIELD OF A CANARD-TYPE CONTROL SURFACE AT A MACH NUMBER OF 2.00

By George A. Wise

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SUMMARY

The influence of triangular-shaped end plates on the lift and the flow field of a canard-type control surface mounted on a symmetrical fuselage was investigated in the Lewis 8- by 6-foot supersonic wind tunnel at a Mach number of 2.00, body angle of attack of 2°, and control-surface deflection angles of 3°, 6°, 8°, and 10°.

The investigation demonstrated that the addition of end plates to a canard-type control surface increased its lift and rearranged the single vortex into a two-vortex system. Perforating the end plates reduced these effects and resulted in a decrease in lift and a change in the flow-field characteristics.

INTRODUCTION

The discontinuity of the flow field at the tip of a lifting surface is known to produce a vortex in the flow field downstream of the tip. For the canard-type missile the tip vortex from the forward control surface can have a significant effect on the performance of an air inlet located in the disturbed region (ref. 1). The results of a previous work (ref. 2) and an examination of the mechanism which causes the tip vortex to be generated indicate that a plate attached to the tip of the lifting surface would cause a redistribution of the pressure gradients around the tip and would therefore affect the strength and distribution of the vortex system.

The effect of end plates on the flow field behind a canard-type control surface was investigated in the NACA Lewis 8- by 6-foot supersonic wind tunnel at a Mach number of 2.00. The control surface and body combination used for this investigation is the same as the short-span configuration of reference 1. The body angle of attack was 2°, and control-surface deflections with respect to the body axis were varied from 3° to 10°. Reynolds number of the test was approximately 2.8×10^{6} based on mean aerodynamic chord of the control surface.

APPARATUS AND PROCEDURE

The pertinent dimensions of the fuselage and control surface, which were also used in the investigation reported in reference 1, are shown in figure 1. The end plates utilized an 80° isoceles triangular plan form to maintain a supersonic leading edge and to prevent pressure bleed around the leading edge at a Mach number of 2.00 and at moderate deflection angles. One phase of the investigation was conducted with perforations in the end plates. The perforations consisted of 1/8-inch holes drilled on 7/16-inch centers over the entire end plate. It was thought that the perforations would help to distribute more evenly the pressure differences across the end plates and thus to reduce the concentrated vortices off the end plates. 2772

The method of measurement at the survey plane is the same as the pitot-tube-and-wedge method used in reference 3. Pitot tubes and wedges were spaced as shown in figure 2, and the wedges were arranged for downwash measurements only. Downwash measurements were corrected by subtracting the value measured at a body and control-surface angle of attack of 0° from the values obtained at other conditions. The Mach numbers measured by the wedges were used to correct the pitot pressures measured at the same locations. The plane of survey was 9.3 mean aerodynamic chord lengths downstream of the midchord of the control surface. Photographs of the various configurations tested and the survey apparatus are shown in figure 3.

Forces on the complete configuration were measured by the use of external tunnel scales. Increments of lift coefficient due to control-surface deflection were obtained by first assuming that the lift due to the control surface was zero at a control-surface deflection of -2° and then subtracting the observed lift coefficient at this condition from the values obtained at other control-surface deflections. The observed lift coefficient at a control-surface deflection of -2° was caused by the body angle of attack of 2°.

In order to aid in the visualization of the flow field behind the control surface, water-tank tests were conducted wherein a fuselage and canard-type control-surface combination was plunged into quiescent water. Photographs were then taken of the resulting pattern formed by aluminum powder floating on the surface of the water. The fuselage was similar to the one used in the tunnel, but the control surface and end plate combination was altered and made proportionally larger to make the phenomena more easily observable.

RESULTS AND DISCUSSION

The characteristics of the flow field in the survey plane are presented in figure 4. In general, the effect of both the solid and perforated end plates was to increase the total area of the disturbed flow

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and to reduce the area of the regions of low pressure; for example, the regions of total-pressure ratio below 80 percent. The addition of perforations to the end plates reduced their effectiveness, as evidenced by the fact that larger regions of low pressure were obtained than with the solid end plates. The downwash and pressure-field plots in figure 4 indicate that the single vortex behind the plain control surface is replaced by two vortices with the addition of end plates. The contours also indicate that, at the survey plane, the cores of the two vortices had rotated about each other with respect to the plane of the end plate, and the angle of rotation increased as the control-surface deflection increased. The rotation of the vortices about each other and the increased angle of rotation with increased control-surface deflection correspond to the "leapfrogging" and shortening of "leapfrog" distance with increasing lift coefficient, respectively, previously found for cruciform wings (ref. 4). Investigations conducted at body angles of attack of 0° and 4° indicated essentially the same results as the 2° case and therefore were not presented.

The rotation of the vortices about each other is illustrated by water-tank photographs in figure 5. The frames show successive body stations for a single plunge of the model with the station number scaled to correspond to distance in inches from the nose of the tunnel model. Increased angle of rotation with increased control-surface deflection is illustrated in figure 6 and can be seen by noting the increased angle between the lines drawn through the vortices.

The variation of the incremental lift coefficient of the control surface with angle of attack is presented in figure 7. It can be seen that the addition of both sets of end plates to the control surface resulted in a substantial increase of the lift coefficient. The increase due to the perforated end plates was slightly lower than that due to the solid end plates. The lift coefficient of the control surface used in figure 7 includes the effects of interference between the wake of the control surface and the fuselage. The effect, however, should be small and would not be expected to alter the form of the plot noticeably.

It was noted previously that the effect of end plates was to reduce the areas of large total-pressure losses at equal control-surface angles of attack. If the various configurations were compared at equal lifts, the smaller control-surface deflection associated with the end-plate configurations would result in even smaller losses in the pressure field than obtained at equal angles of attack.

The upper leading edge of the end plate becomes subsonic at a body angle of attack of 2° and a control-surface deflection of 10°. At this condition, however, the contours indicate no departure from the trends indicated by the contours for the other control deflections, and, therefore, the subsonic leading edge apparently had little effect on the general results.

SUMMARY OF RESULTS

The influence of triangular end plates on the flow field approximately 9.3 mean aerodynamic chord lengths downstream of a canard-type control of trapezoidal plan form was investigated in the Lewis 8- by 6-foot supersonic wind tunnel at a Mach number of 2.00. The following results were obtained:

1. The end plates redistributed each vortex from a plain control surface into a two-vortex system. These two vortices rotated about each 2772
other, and the angle of rotation increased with increasing control-surface deflection.

2. The addition of end plates increased the total area of the disturbed region and decreased the area of large total-pressure losses.

3. An increase in lift coefficient was obtained with the addition of end plates to the plain control surface.

4. Perforating the end plates reduced their effectiveness in redistributing the flow field and in increasing the lift.

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National Advisory Committee for Aeronautics
Cleveland, Ohio

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1. Obery, L. J., and Krasnow, H. S.: Influence of a Canard-Type Control Surface on the Internal and External Performance Characteristics of Nacelle-Mounted Supersonic Diffusers (Conical Centerbody) at a Rearward Body Station for a Mach Number of 2.0. NACA RM E52F16, 1952.

2. Boatright, William B.: Total-Pressure and Schlieren Studies of the Wakes of Various Canard Control Surfaces Mounted on a Missile Body at a Mach Number 1.93. NACA RM L52I29, 1952.

3. Fradenburgh, Evan A., Obery, Leonard J., and Mello, John F.: Influence of Fuselage and Canard-Type Control Surface on the Flow Field Adjacent to a Rearward Fuselage Station at a Mach Number of 2.0 - Data Presentation. NACA RM E51K05, 1952.

4. Spreiter, John R.: Downwash and Sidewash Fields Behind Cruciform Wings. NACA RM A51L17, 1952.

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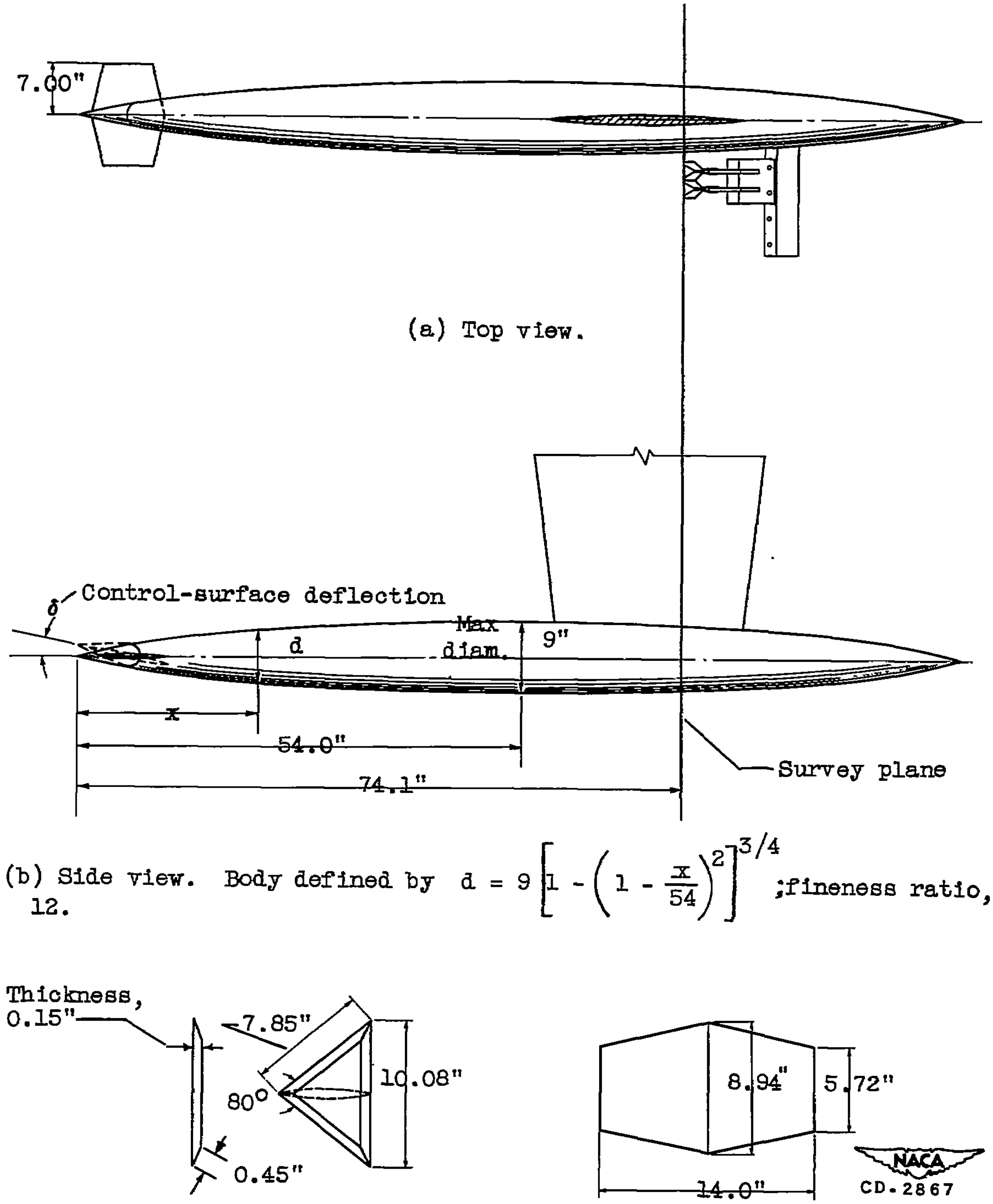

(a) Top view.

(b) Side view. Body defined by $d = 9\left[1 - \left(1 - \frac{x}{54}\right)^2\right]^{3/4}$; fineness ratio, 12.

(c) End plate.

(d) Control surface. Mean aerodynamic chord, 7.33".

Figure 1. - Sketch of model, canard, and end plate.

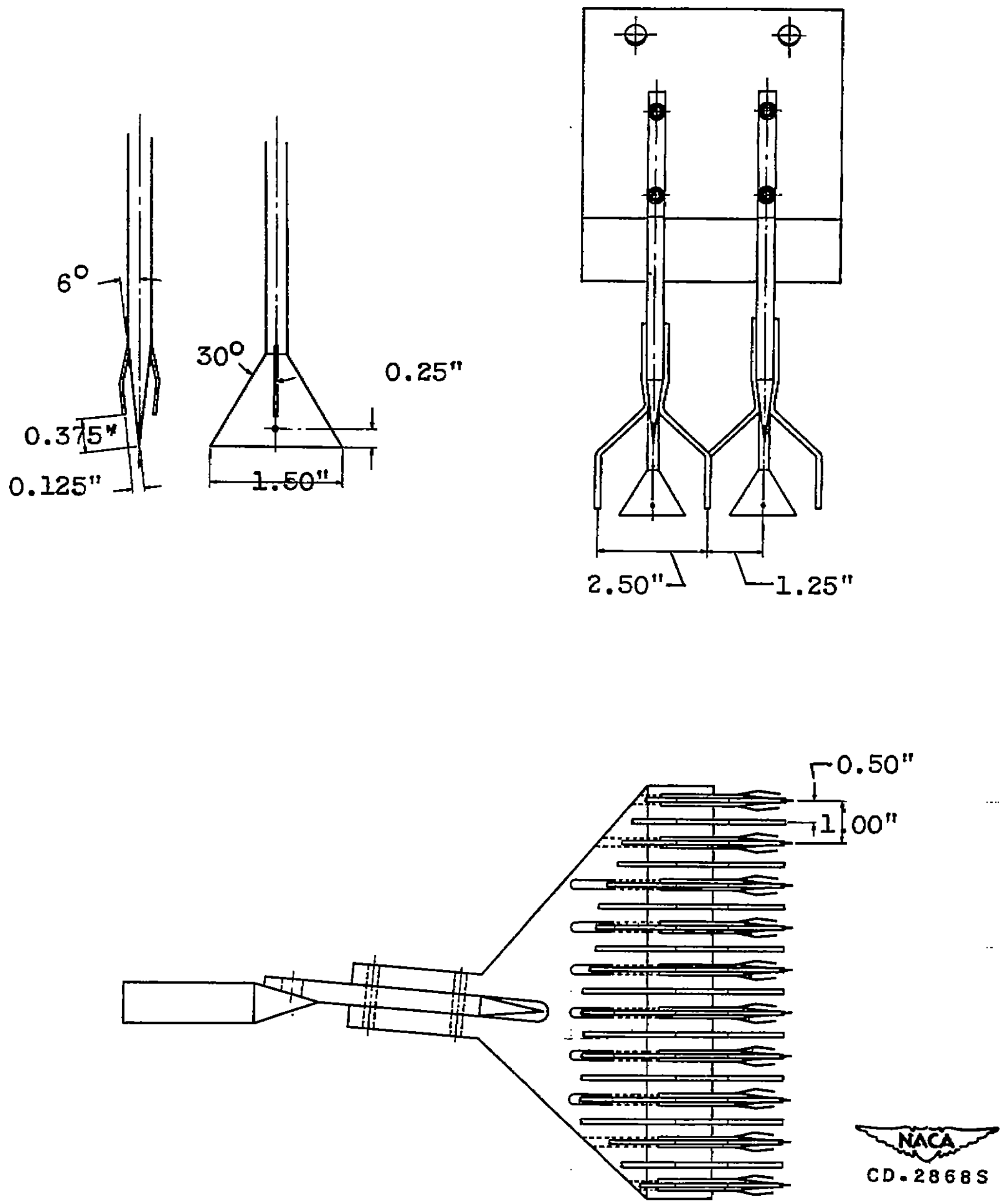

Figure 2. - Sketch of survey rake.

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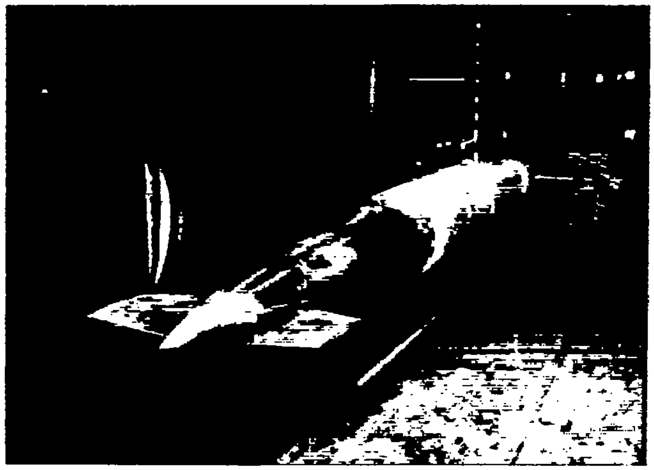
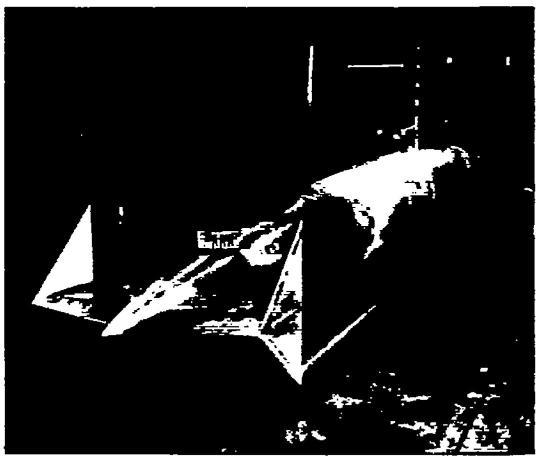
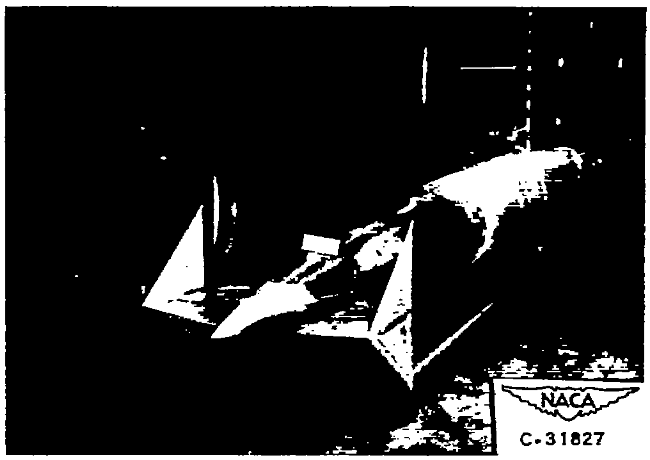
(a) Survey rake.



(b) Control surface.



(c) Control surface with solid end plates.



(d) Control surface with perforated end plates.

Figure 3. - Survey rake, control surface alone, and control surface with solid end plates and with perforated end plates.

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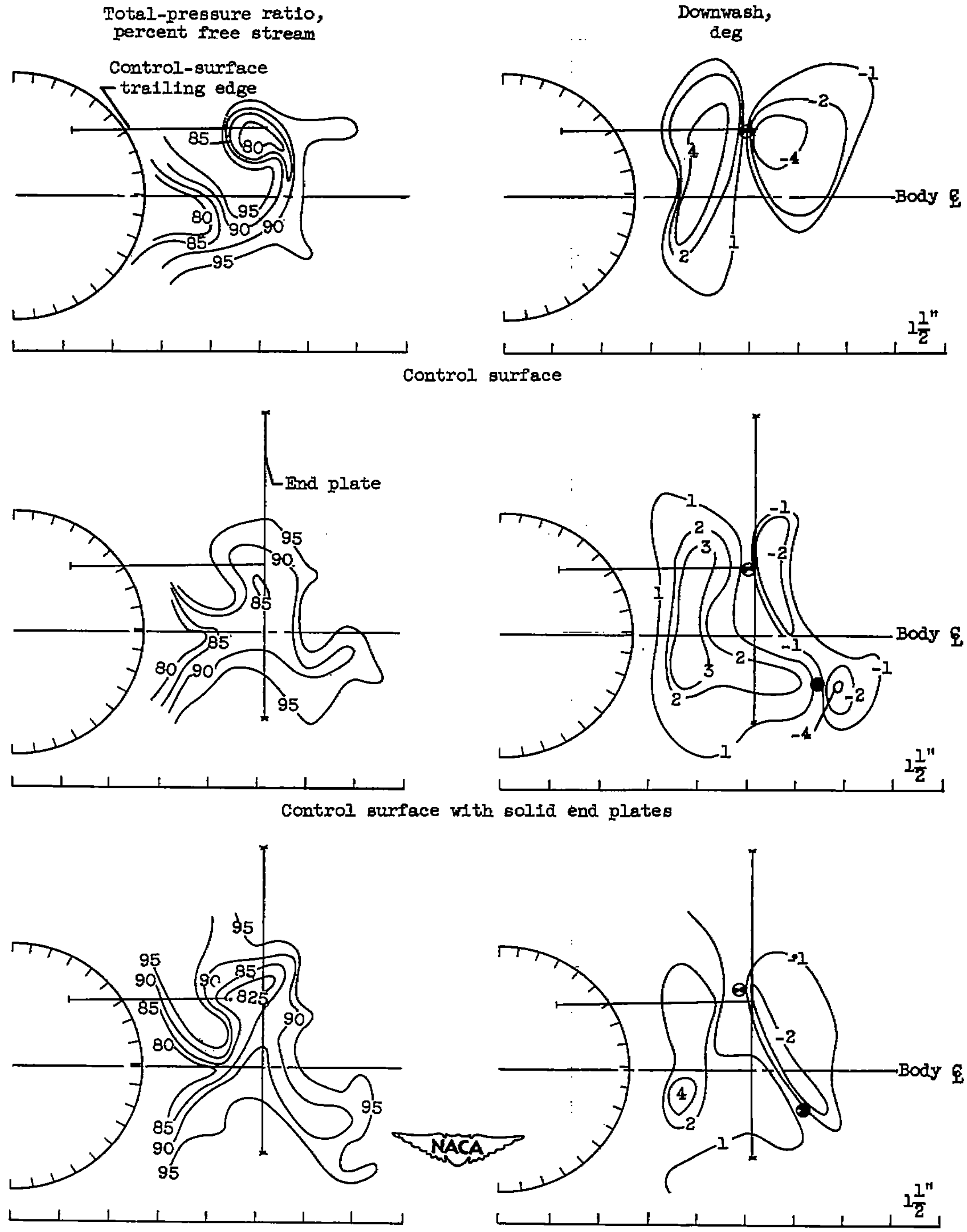
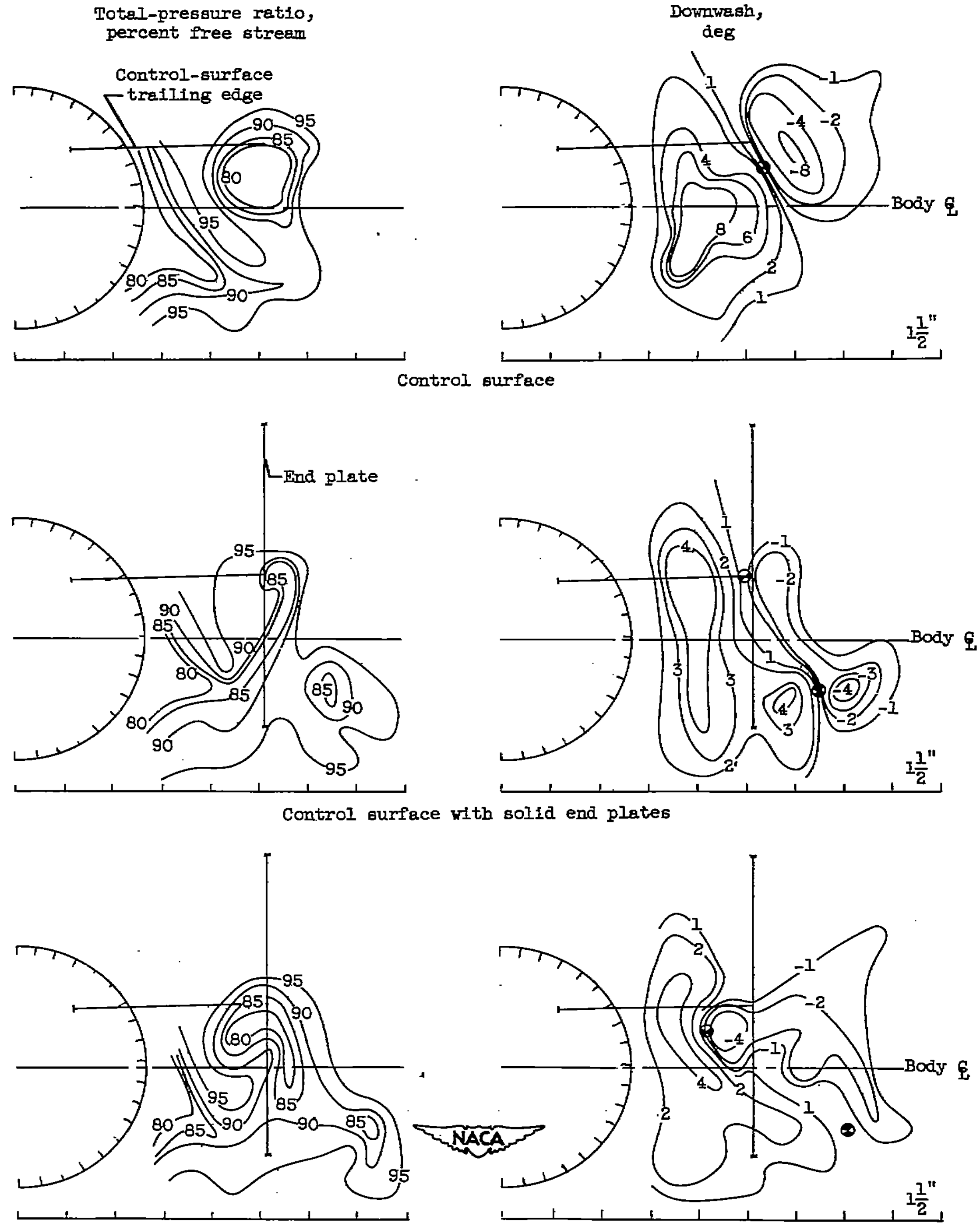


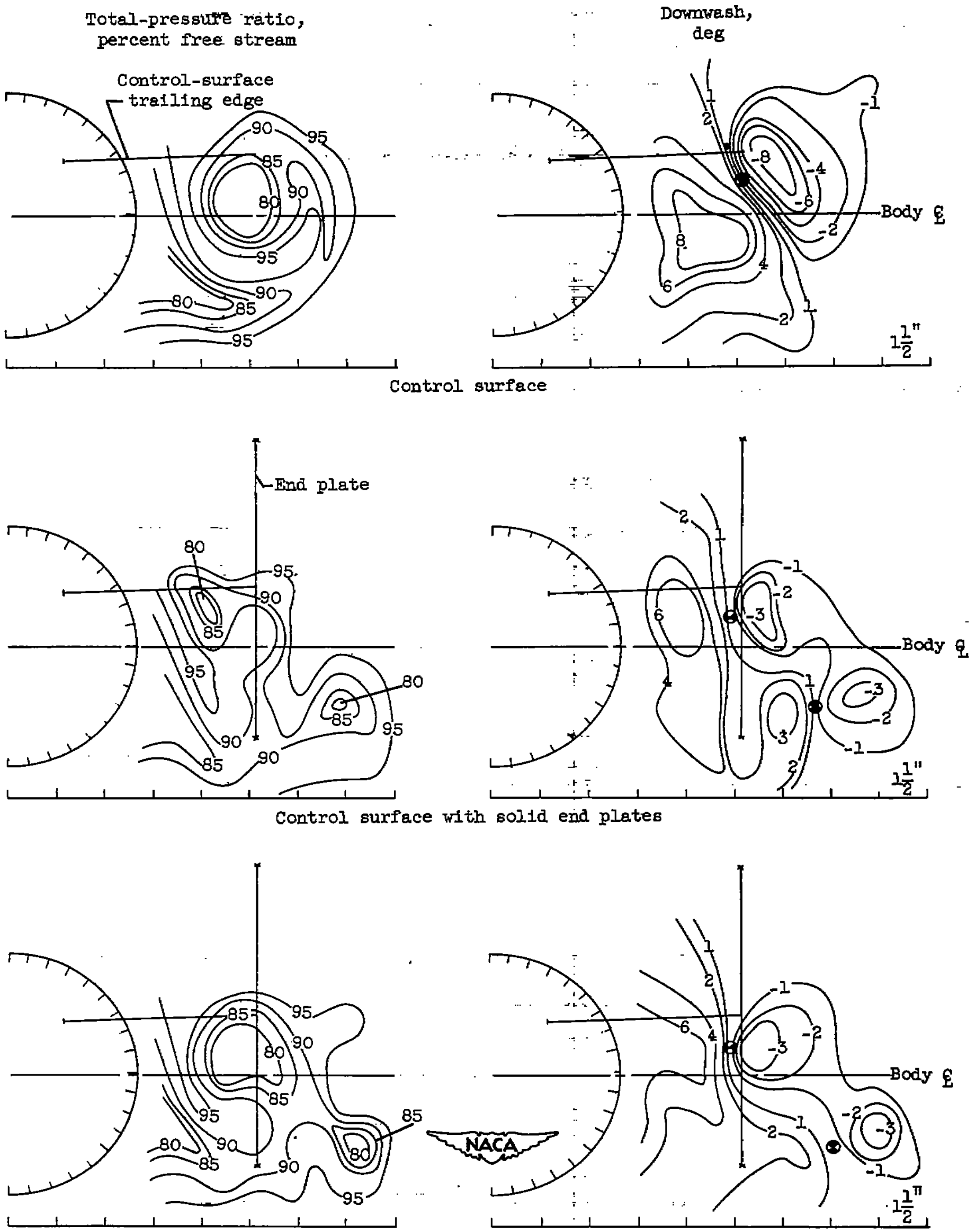
(a) Control-surface deflection, 3°.

Figure 4. - Total-pressure-ratio and downwash contours for three configurations.



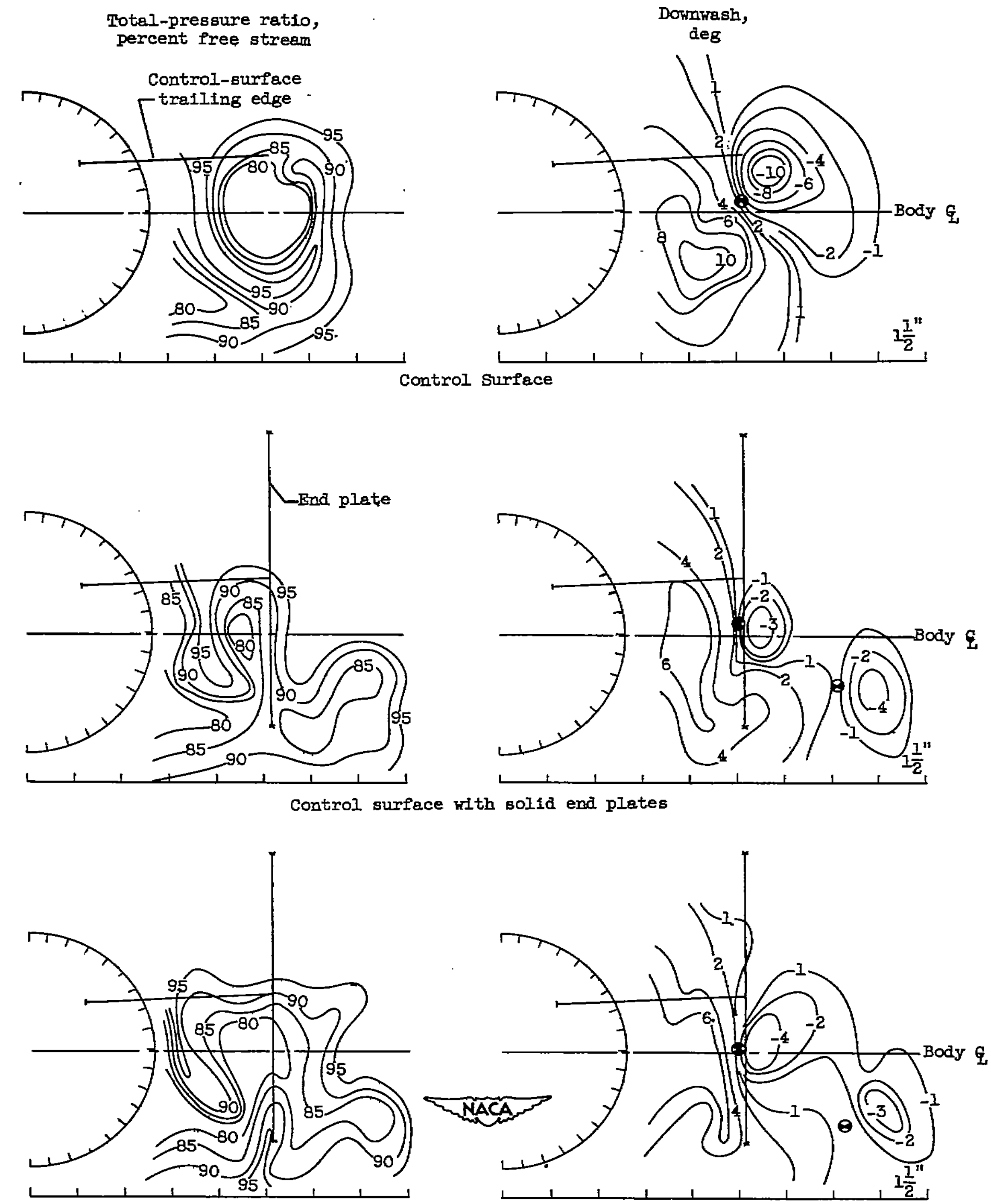
(b) Control-surface deflection, 6°.

Figure 4. - Continued. Total-pressure-ratio and downwash contours for three configurations.



(c) Control-surface deflection, 8°.

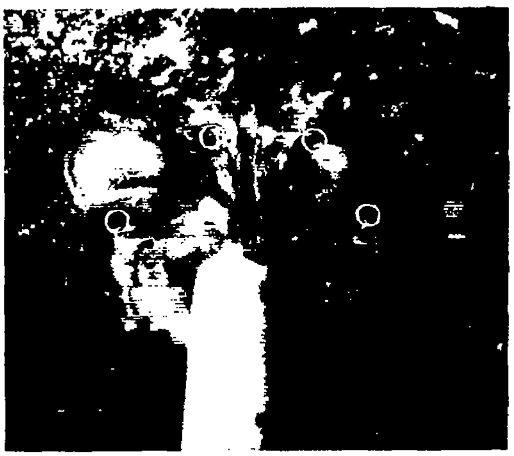
Figure 4. - Continued. Total-pressure-ratio and downwash contours for three configurations.



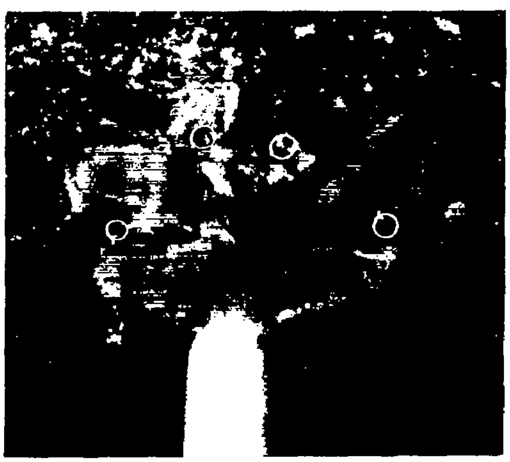
(d) Control-surface deflection, 9°50'.

Figure 4. - Concluded. Total-pressure-ratio and downwash contours for three configurations.

(a) Above water.



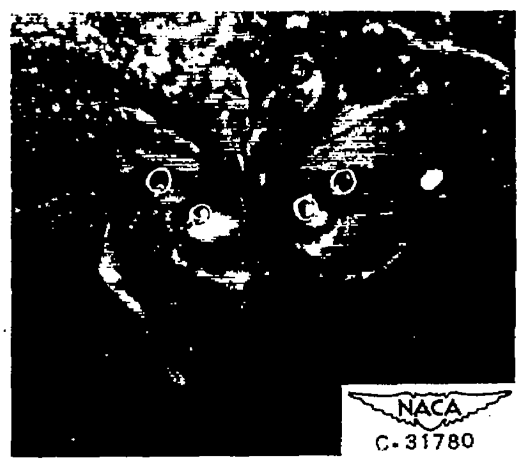
(b) Station 50.



(c) Station 63.

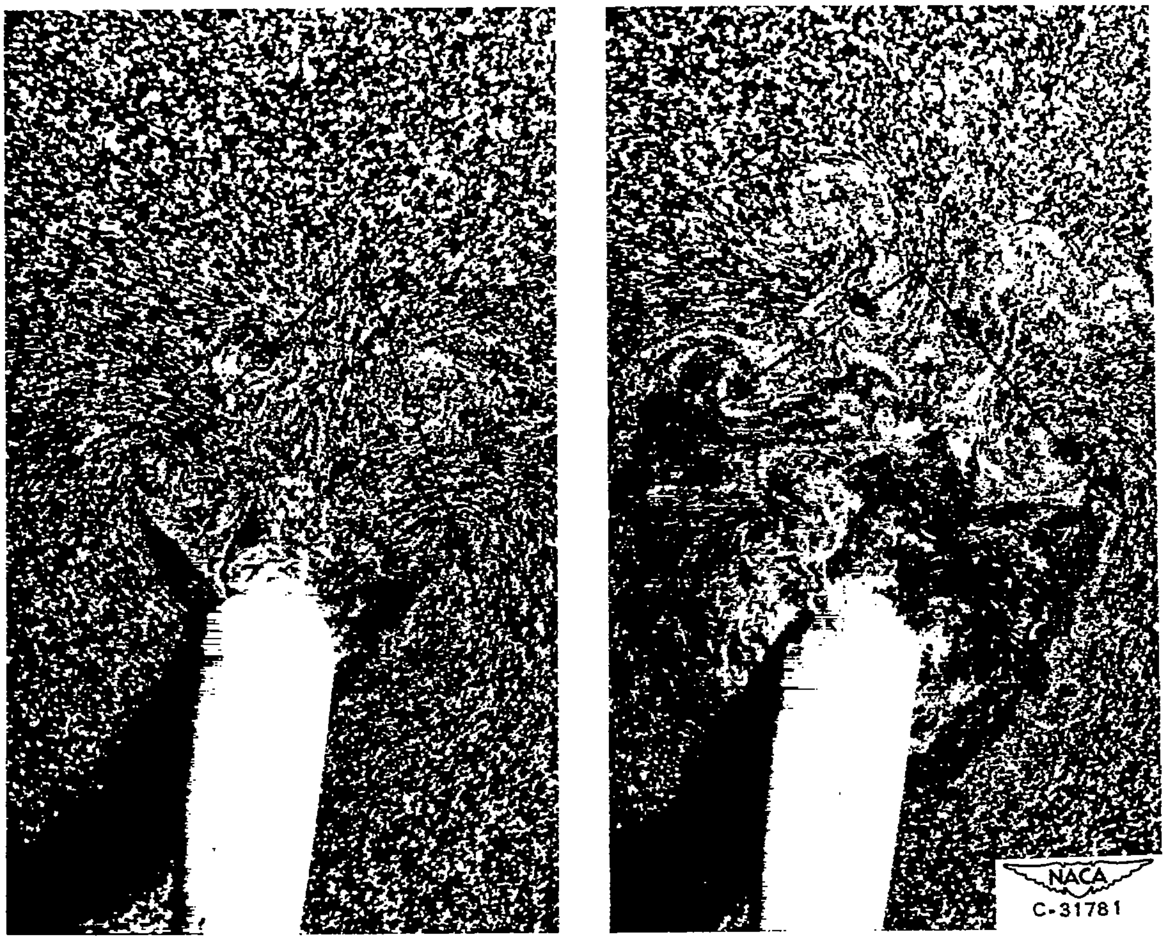
(d) Station 75.

(e) Station 88.



(f) Station 101.

Figure 5. - Water-tank photographs showing rotation of vortices off end plates about each other at angle of attack of 20°.



(a) Angle of attack, 15°.

(b) Angle of attack, 20°.

Figure 6. - Water-tank photographs showing increased angle of rotation with increased angle of attack at station 74.

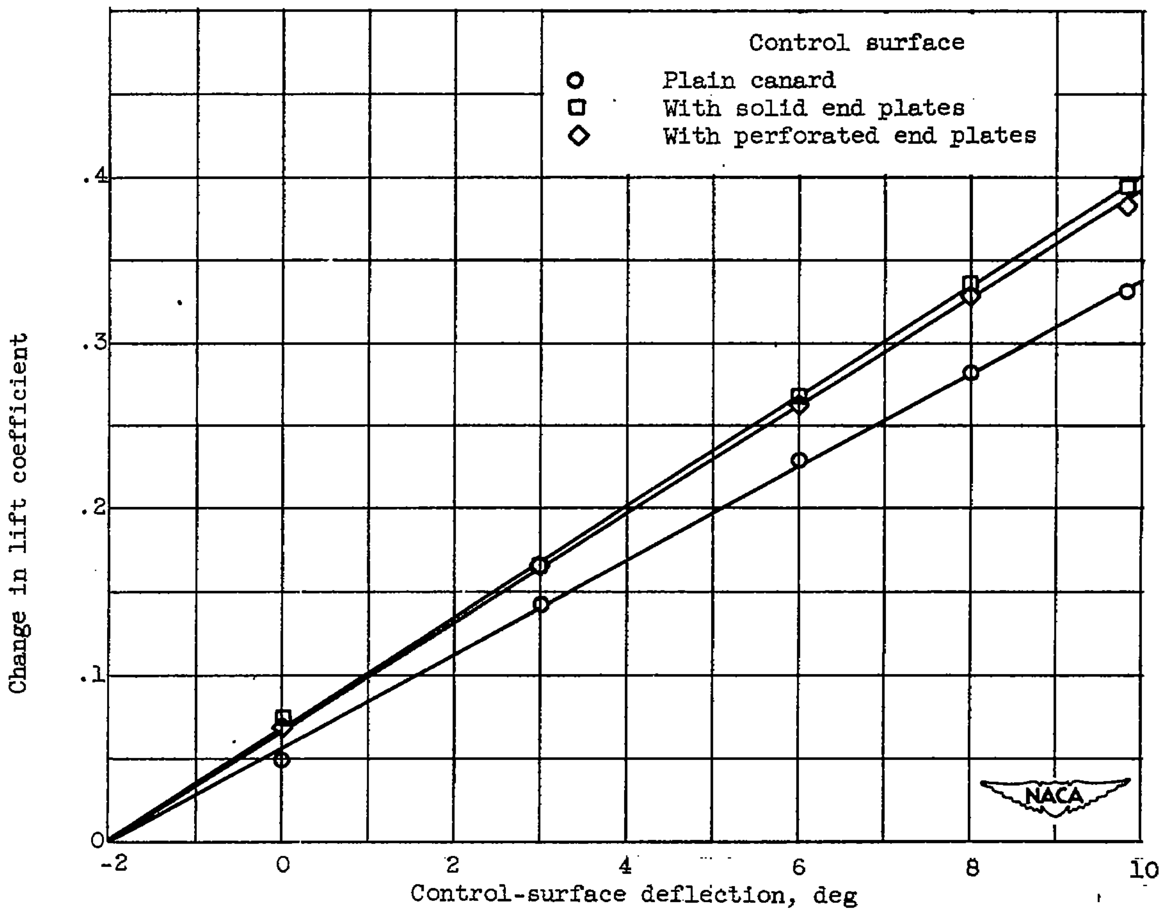


Figure 7. - Variation of lift coefficient with control-surface deflection. Body angle of attack, 2°.

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